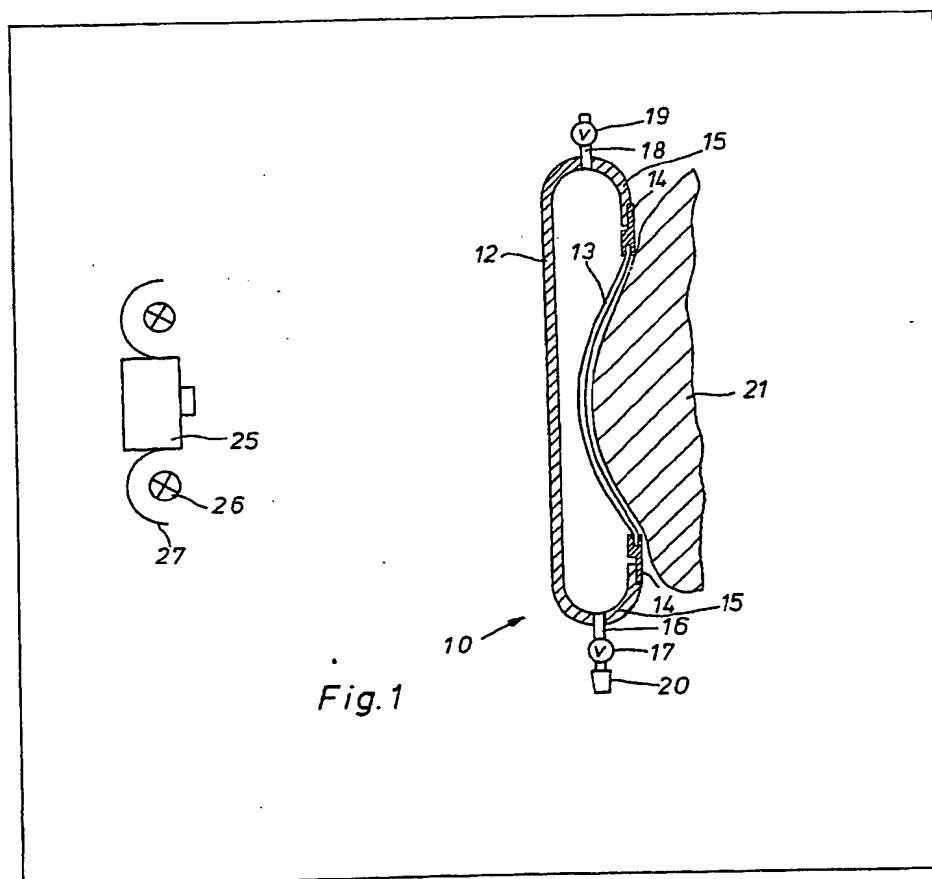


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## (54) Temperature indicator

(57) A thermographic device and method wherein a material having temperature-dependent colour characteristics is incorporated into a flexible elastically extensible detector 13 forming part of the wall of gas-tight envelope 12-15-14 having means such as conduit 16 via which gas can be pumped to bring the detector into uniform surface contact with a body 21, e.g. part of the human body, whose temperature distribution pattern is to be determined. The detector may comprise a temperature-responsive layer of liquid crystals of the cholesteric type. In an alternative form of the device and method the detector is attachable to the body to be tested so that a gas-tight space is defined by the detector and body and the detector can be brought into uniform surface contact with the body by withdrawing gas from such space.



The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.

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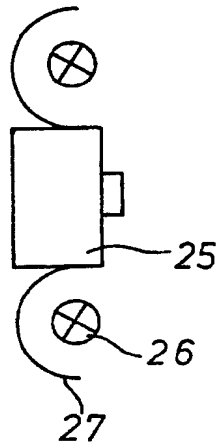


Fig. 1

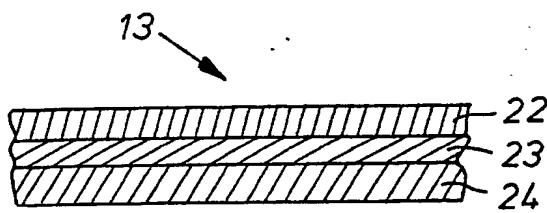


Fig. 2

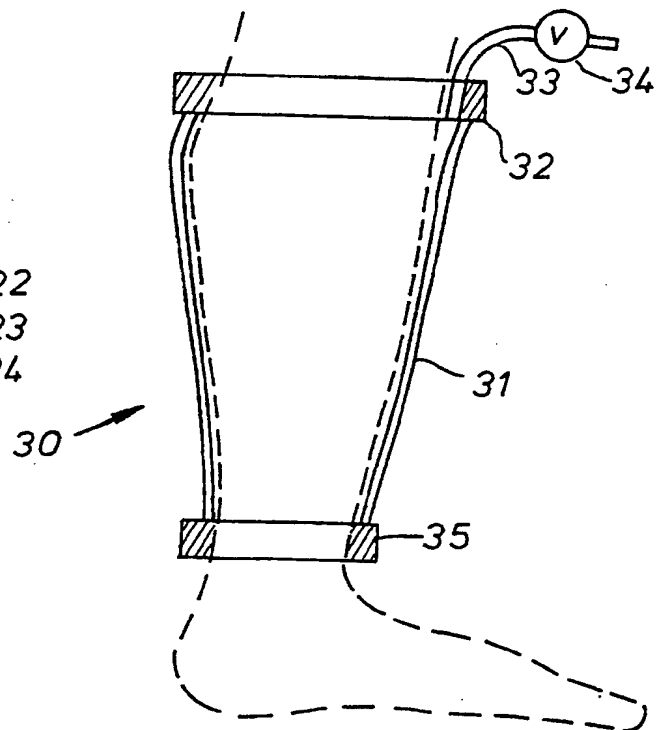


Fig. 3

## SPECIFICATION

**Thermographic device and method of testing a body to determine its temperature distribution pattern**

5 This invention relates to thermographic devices incorporating substances which indicate temperature differentials in terms of colour patterns. The invention also relates to a method of testing a body to determine its temperature distribution pattern or profile. 5

In the medical field the measurement of temperature forms a basis for diagnosis and localization of illness e.g. inflammation in a human body. Localized heating of tissue can be detected by placing a thermally sensitive member directly in contact with the member whose temperature pattern or profile is to be determined. For that purpose liquid crystals of the cholesteric type have been introduced as a suitable detector of heat so as to obtain a different colour as a function of temperature. 10

Liquid crystals are an intermediary state of matter between solid crystal and liquid, which state is called mesophase. In this state the molecules still geometrically organized, e.g. in a layer pattern, can slip against each other. Thin films of cholesteric liquid crystals exhibit the property upon interaction with light to selectively reflect part of the light as a function of wavelength and temperature (ref. Andreas Huth et al., 15 Fotografische Flüssigkristall-Hautthermometrie und -grafie, Bild und Ton 8/1977 p. 233-240). By "cholesteric" crystals is meant crystals of which the molecule arrangement consists of layers wherein the molecules lie flat and parallel to each other, and successive layers are rotated through a certain angle with respect to the previous layer. These molecules are esters of cholesterol e.g. acetate, benzoate, stearate, etc. Different mixtures of cholesteric crystals can be formed which are suitable for different temperature ranges. 20

For determining the temperature profile of parts of the human body by means of such liquid crystal materials it is known to apply the crystals directly to the skin, possibly after painting it black to enable the iridescent colours of the crystals to be seen to better effect. This procedure is very inconvenient. The skin has to be washed after the examination and the crystal mixture cannot be used again. Moreover the procedure cannot be used for examining sites of open wounds. 25

It is known to avoid the problems associated with direct coating of the skin by the crystal composition by incorporating the crystals in a sheet material or membrane, e.g. a sheet material comprising a dark carrier sheet bearing a cholesteric crystal layer, which can be laid in contact with the skin. The liquid crystal material can be incorporated in microcapsules. Such sheets can be held in a frame and while in contact with the body under examination can be photographed to provide colour records indicative of temperature profile, which can be interpreted by comparing them with reference patterns. The making of such photographic records is described in Acta Thermographica Vol. 1, No. 3, 1976 p. 172-175. 30

In the United States Patent 3,852,092 a thermally responsive elastic membrane is provided which membrane incorporates encapsulated material having anisotropic optical properties, e.g. a cholesteric liquid crystalline material. The membrane is formed from a material having the desired elasticity within which are provided the anisotropic material in encapsulated form as well as particles of another material which is incompressible relative to the capsules containing the cholesteric substances. Such particles of an incompressible material are larger in size than the capsules incorporating the cholesteric substances so as to protect the latter from internal compressive stresses caused within the elastic membrane by flexing or stretching thereof. 40

When using the known thermographic sheets or membranes it is difficult to obtain good thermographs of certain curved body surfaces due to the problem of ensuring close conformity of the sheet or membrane to the surface contour of the body. The attempt to manipulate the sheet or membrane into correct position can prove painful to the patient if the site to be examined is inflamed or affected by injury. 45

The present invention aims to provide a thermographic device which facilitates good thermographic examination, particularly of variously curved surface areas of the human body.

According to the present invention there is provided a thermographic device for indicating the temperature distribution pattern of a body, said device comprising a flexible elastically extensible temperature detector for contact with a body to be tested, such detector comprising a layer containing a substance or mixture of substances which when the layer is non-uniformly heated within a certain temperature range confers on any given area of that layer a colour depending on its temperature, characterized in that said detector forms part of the wall of a gas-tight envelope or has fixed or removable means whereby it can be attached to a body to be tested so that a gas-tight space is defined by the detector and that body, and in that there is means whereby gas can be forced into or withdrawn from such envelope or space to promote uniform surface contact between said detector and said body. 50 55

According to the present invention there is further provided a method of testing a body to determine its temperature distribution pattern, which method comprises the step of placing in surface contact with said body a flexible elastically extensible temperature detector comprising a layer containing a substance or mixture of substances which when the layer is non-uniformly heated within a certain temperature range confers on any given area of that layer a colour which depends on its temperature, characterized in that gas is forced into or withdrawn from a space on one or the other side of said detector to promote conformity of said detector with the surface profile of the body. 60

A uniform pressure of the temperature detector against the surface to be examined is important for correct heat transmission. A correct reading is not obtained if locally different pressures are applied. The device and 65

method of the present invention provide an improvement over devices and methods wherein pressure is applied mechanically since pressure applied by a gas i.e. pneumatically will be more uniformly distributed.

Embodiments of devices and an embodiment of a temperature detector element for use according to the present invention are illustrated in the accompanying drawings.

5 *Figure 1* represents a cross sectional view of a thermographic device according to the present invention. 5  
*Figure 2* represents a cross sectional view of the heat-sensitive layer structure applied in the devices of figure 1 and figure 3.

*Figure 3* represents a cross sectional view of another thermographic device according to the invention.

The device shown in figure 1 represents the cross section of an envelope or sac which is generally 10  
 rectangular in front view (not shown). The envelope has a front wall 12, which is transparent. It can be made, 10  
 e.g., of glass or polymethylmethacrylate. The piece of transparent material serving as a window is shaped to provide the peripheral wall of the envelope and a marginal portion 15 of the rear wall of the envelope. This 15  
 portion 15 defines an opening in which a rigid frame 14 of heat insulating material is gas-tightly but removably fitted. The frame carries an elastically extensible temperature detector 13. The envelope 10 is 15  
 provided with a conduit 16 in which there is a non-return valve 17 and with a conduit 18 in which there is a pressure relief valve 19. The end of conduit 16 has a conical end fitting 20 for gas-tight connection with a 20  
 pump system (not shown) or pressure vessel provided with a pressure relief valve to adapt the pressure to the required circumstances. When soft tissues of a body, e.g. a mamma 21 as shown in figure 1, has to be examined the pump system is operated to establish a reduced pressure in the envelope 10. Due to that 20  
 reduced internal pressure the elastic detector 13 assumes an inwardly curved form as shown so that it can conform much more closely to the profile of the mamma 21 to be examined.

The temperature detector 13 comprises a sheet material of composite structure as shown in figure 2. The material comprises an elastically deformable black resin sheet 22 coated with a temperature-responsive 25  
 layer 23 of liquid crystals of the cholesteric type. Said layer 23 in its turn is covered with a resin sheet 24, 25  
 which is transparent to light, is likewise elastically deformable and shields the liquid crystal mass from contact with the ambient air.

The cholesteric-type liquid crystals may be encapsulated and in that form incorporated in a binder, e.g. gelatin, containing optionally (a) plasticizing agent(s) forming an elastically deformable continuous phase in the heat-sensitive colouring layer 23. The encapsulation of cholesteric liquid crystals may proceed according 30  
 to the technique described in the German Patent 1,648,266.

As an alternative the sheet 22 can be dispensed with so that the layer containing the encapsulated liquid crystals is the outermost layer and is carried by sheet 24. Such a device can be used e.g., for examination of a body which has a neutral colour, e.g. is painted black or has an inherent black colour. The direct contact of the binder layer containing the encapsulated cholesteric liquid crystals with the body to be examined 35  
 improves the image sharpness, due to less lateral heat diffusion, and increases the speed of image formation.

The transparent resin sheet 24 is likewise not strictly necessary because the cholesteric crystals can be encapsulated and incorporated in a self-sustaining flexible and elastically extensible binder layer.

The black resin sheet 22 is made, e.g. of an elastomer, e.g. a natural or synthetic rubber incorporating 40  
 dispersed black particles, e.g. carbon black particles that offer a neutral image background and increase the thermal conductivity of the sheet. Instead of black particles to be incorporated in the sheet 22 the latter may be coated with a black layer, e.g. an elastic gelatin layer dyed with a black organic dye or carbon black.

According to a particular embodiment the black layer has the thickness and structure of a black layer described in the published Dutch Patent Application 7609084 for use in a thermographic sheet.

45 The resin sheet 24 may be made of a transparent natural or synthetic elastomer resin, e.g. a transparent silicone resin. Such resins are described, e.g., by D.H.Solomon in "The Chemistry of Organic Film Formers", John Wiley & Sons, Inc. New York (1967) p. 316-319.

Information on natural rubber and synthetic rubber can further be found in the "Textbook of Polymer Chemistry" of F.W.Billmeyer, Jr., Interscience Publishers, Inc., New York (1957) p. 454-479.

50 If necessary the sheet 22 and/or sheet 24 is or are provided with one or more subbing layers improving the adherence of layer 23 thereto.

In figure 1 the enclosure 10 is used for recording the colour pattern in conjunction with a camera 25 provided with a ring flash lamp 26 and reflector 27.

According to an embodiment of the method of the present invention the device of figure 1 is operated with 55  
 increased pressure instead of with reduced pressure. Such can be simply done by closing the valve 17 of the enclosure 10 and pressing the body part to be examined, e.g. the back of a hand, against the layer structure 13. Hereby the pressure inside the enclosure 10 increases. Due to the elasticity of said layer structure 13 and the pressure built up in the enclosure 10 the heat-sensitive layer closely follows the profile or contour of the body part.

60 According to another embodiment of the method of the invention that can be carried out with a device containing the elements of figure 1 the pressure inside the enclosure 10 is increased by introducing gas e.g. air in the enclosure 10 while the frame 14 of the layer structure 13 is pressed against the surface surrounding a cavity of the body to be examined. Because of the inside pressure and the elasticity of the layer structure 13 the heat-sensitive layer 23 is deformed to conform to the body surface of the cavity and allows the 65  
 examination of the temperature pattern inside the cavity.

Referring now in detail to figure 3 the cross-section of an elastically extensible article 30 has the form of a stocking-part designed for examination of the temperature pattern of a leg (shown with dotted line). The element 31 of the stocking has the composition of the layer structure 13 of figure 2. Said element 31 is gastightly attached to an upper elastic garter 32 fitted to a flexible conduit 33, e.g. rubber tube, including a non-return pressure valve 34. The stocking missing the foot part is hermetically sealed to the underpart of the leg by a second elastic garter 35, which forms a completely gastight seal with the leg. After the stocking is put around the leg the space left between the element 31 and the surface of the leg is evacuated with a hand-driven suction pump (not shown), e.g. a rubber pear provided with a one-way exhaust valve. Hereby the layer structure 31 comprising the heat-sensitive layer comes into close contact with all the surface parts of the leg and a good thermally conductive contact is obtained.

The thermosensitive element can have the composition as set forth for the membrane in US Patent 3,852,092.

Figure 3 serves as an example of any device wherein the heat-sensitive layer structure has the form of a sleeve or tube having fixed means whereby it can be attached to a body said fixed means being here two elastic sealings in the form of garters. According to another embodiment a cover i.e. a bag is used, which is provided with only one elastic seal or a removable tie member e.g. removable garter, cord, ribbon, belt, expandable metal chain etc.

Temperature control of the neighbourhood may be desirable in order to maintain the heat-sensitive layer within the temperature range in which the mesophase of the cholesteric crystals exists. For example, a thermal radiation unit, e.g. in the form of one or more incandescent lamps, may bring the surrounding air to a proper temperature. The device of figure 3 e.g. may be used in easily adjustable temperature conditions in a transparent water tank with thermostatic control. Conceivably the temperature stabilization would in some cases be used to extract heat from the heat-sensitive member and to maintain it at a background temperature that is below ambient temperature. When the latter is not expected to vary beyond the range in which the heat-sensitive cholesteric crystals are in the mesophase temperature stabilization is not required but it may be used to enhance sensitivity.

Cholesteric liquid crystalline substances suited for use in the present invention are described, e.g., in the United States Patent 3,114,836.

A particular example of a cholesteric liquid crystalline mixture has the following composition:

	% by weight
cholesterol nonate	45
cholesterol linoleate	50
cholesterol chloride	5

This composition is sensitive over a temperature range of from about 1° to 100°C.

Other suitable encapsulated cholesteric material is commercially available and e.g. sold by National Cash Register Company U.S.A. under designations R-30, R-33, R-35 and R-37 collectively covering the temperature range of 30°C to 40°C.

Still other compositions are described in Ber. Bunsenges., 77 nr. 1, 1973, page 21.

In cholesteric thermography the picture is always coloured in a succession of colours from cold to warm going normally from black (the background colour) to red, yellow, green, light blue and dark blue.

While the present invention has been described in only a few embodiments, it will be apparent to those skilled in the art that the practice of the present invention may assume other forms without departing from the spirit and scope thereof.

## CLAIMS

1. A thermographic device for indicating the temperature and distribution pattern of a body, said device comprising a flexible elastically extensible temperature detector for contact with a body to be tested, such detector comprising a layer containing a substance or mixture of substances which when the layer is non-uniformly heated within a certain temperature range confers on any given area of that layer a colour depending on its temperature, characterized in that the said detector forms part of the wall of a gas-tight envelope or has fixed or removable means whereby it can be attached to a body to be tested so that a gas-tight space is defined by the detector and that body, and in that there is means whereby gas can be forced into or withdrawn from such envelope or space to promote uniform surface contact between said detector and said body.

2. A device according to claim 1, wherein said heat-sensitive substance or the heat-sensitive substances in said mixture is or are cholesteric liquid crystals.

3. A device according to claim 2, wherein said crystals are applied as a layer between two elastically deformable resin sheets, one of which is in contact with the ambient outside of the envelope and has a black colour or is coated with a layer having a black colour, and the other sheet is transparent to visible light.

4. A device according to any of the preceding claims, wherein said crystals are encapsulated and are incorporated as such in an elastic binder so as to form a heat-sensitive layer.

5. A device according to any of the preceding claims, wherein the means whereby gas can be forced into

said envelope is a non-return valve and the means whereby gas can be withdrawn from said envelope is a pressure relief valve.

6. A device according to any of the preceding claims, wherein the envelope includes a transparent window and opposite thereto an opening in which a rigid frame containing said detector can be gastightly and removably attached.

7. A device according to any of the claims 1 to 5, wherein the detector is in the form of a tube or a bag that can be gastightly arranged around a body or body parts to be examined by means of one or more elastic sealings.

8. A device according to claim 7, wherein one of said sealings is in the form of a garter provided with an exhaust conduit for the envelope formed by said sealing(s), the detector and the wall of said body or body part.

9. A method of testing a body to determine its temperature distribution pattern, which method comprises the step of placing in surface contact with said body a flexible elastically extensible temperature detector comprising a layer containing a substance or mixture of substances which when the layer is non-uniformly heated within a certain temperature range confers on any given area of that layer a colour which depends on its temperature, characterized in that gas is forced into or withdrawn from a space on one or the other side of said detector to promote conformity of said detector with the surface profile of the body.

10. A method according to claim 9, wherein in the testing a device according to any of claims 1 to 8 is used.